BULLETIN OF THE CHEMICAL SOCIETY OF JAPAN, VOL. 44, 1062—1067 (1971)

Sterically Controlled Syntheses of Optically Active Organic Compounds. XIII. Catalytic Hydrogenation of Symmetric Substrates in the Presence of Asymmetric Molecules[1)]

Takao YOSHIDA and Kaoru HARADA

Institute of Molecular Evolution and Department of Chemistry, University of Miami, Coral Gables, Florida 33134, U.S.A.

(Received August 10, 1971)

Several organic acids which contain C=O, C=N, and C=C double bonds are catalytically hydrogenated in the presence of various optically active organic bases by the use of several solvent systems. Effects of bases and solvents on the optical activities of the products are examined.

Many asymmetric hydrogenation reactions have been reported;[2-7)] however, only few reports on the asymmetric hydrogenation using symmetric substrate and catalyst in the presence of asymmetric molecules have appeared in the literature. Lipkin and Stewart[8)] reported the catalytic hydrogenation of β-methylcinnamate and β-(α-naphthyl)-cinnamate with hydrocinchonine, in which a small degree of asymmetric hydrogenation was demonstrated. Nakamura[9)] reported asymmetric hydrogenation of acetophenone oxime in the presence of *l*-menthoxyacetic acid.

In this paper, catalytic hydrogenations of various symmetric organic acids which contain C=O, C=N, and C=C double bonds were carried out by using several solvent systems in the presence of asymmetric organic bases. The substrates used were: benzoylformic acid, α-acetamidoacrylic acid, α-acetamidocinnamic acid, β-phenylpyruvic acid, and α-oximino-propionic acid. Optically active organic bases used were: *l*-sparteine, *l*-ephedrine, (S)-(−)- and (R)-(+)-α-methylbenzylamine, (R)-(+)-α-ethylbenzylamine, and (S)-(−)- and (R)-(+)-α-(1-naphthyl)ethylamine. The

1) Contribution no. 163 of the Institute of Molecular Evolution, University of Miami. Part XII, K. Harada and T. Yoshida, *Chem. Commun.*, **1970**, 1071.
2) S. Akabori, T. Ikenaka, and K. Matsumoto, *Nippon Kagaku Zasshi*, **73**, 112 (1952).
3) Y. Izumi, M. Imaida, H. Fukawa, and S. Akabori, This Bulletin, **36**, 21 (1963).
4) J. C. Sheehan and R. E. Chandler, *J. Amer. Chem. Soc.*, **83**, 4795 (1961).
5) R. G. Hiskey and R. C. Northrop, *ibid.*, **83**, 4798 (1961).
6) K. Harada, *Nature*, **212**, 1571 (1967); *J. Org. Chem.*, **32**, 1790 (1967).
7) J. Mathieu and J. Weill-Raynal, *Bull. Soc. Chim. Fr.*, **1968**, 1211.
8) D. Lipkin and T. D. Stewart, *J. Amer. Chem. Soc.*, **61**, 3295 (1939).
9) Y. Nakamura, *Nippon Kagaku Zasshi*, **61**, 1051 (1940).

solvents used were: water, methanol, ethanol, isopropanol, *t*-butanol, and dioxane. Results are summarized in Tables 1, 2, and 3 and in Figs. 1, 2, and 3.

In Fig. 1, optical purities of mandelic acid (reaction A), alanine (reaction B), phenylalanine (reaction C), and β-phenyllactic acid (reaction D) prepared in the presence of *l*-sparteine by the use of various solvents are presented. The discontinuity of optical purity curves in reactions A, B, and C by the use of various solvents is observed between methanol and ethanol, and in reaction D, discontinuity is found between ethanol and isopropanol.

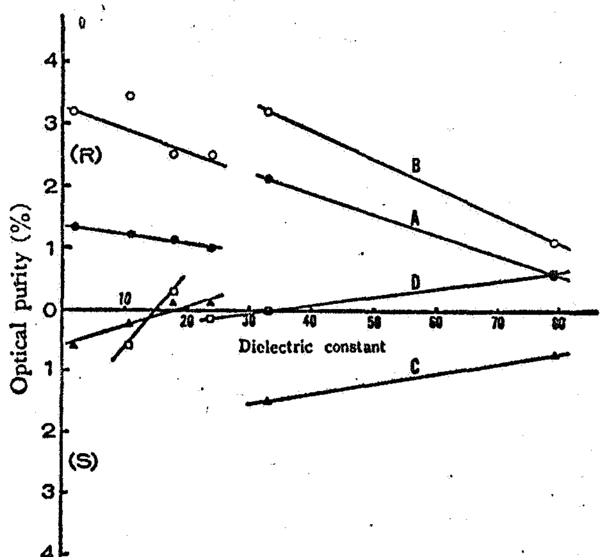


Fig. 1. Catalytic hydrogenation in the presence of *l*-sparteine.
A Benzoylformic acid+*l*-sparteine
B α-Acetamidoacrylic acid+*l*-sparteine
C α-Acetamidocinnamic acid+*l*-sparteine
D Phenylpyruvic acid+*l*-sparteine

In Fig. 2, the optical purity of mandelic acid (reaction E), alanine from α-acetamidoacrylic acid (reaction F), alanine from α-oximino-propionic acid (reaction G), and β-phenyllactic acid (reaction H) are shown. In reaction G, optical purity of alanine from α-oximino propionic acid is rather high and the value reaches 10% by the use of isopropanol. Optical activity of β-phenyllactic acid reaches 7.5% by the use of methanol. The discontinuity of optical purity curves of the products is found in all reactions E, F, G, and H. Inversion of configuration of the products is observed in reactions E, F, and G.

In Fig. 3, alanine formation from α-acetamidoacrylic acid by the use of various optically active bases is presented. In reactions I and J, S-(—)-α-methylbenzylamine and (R)-(+)-α-methylbenzylamine are used respectively for the synthesis of alanine. The optical purity curve of reactions I and J are similar in magnitude but are opposite in sign. The antipodal results are also obtained in the formation of alanine by the use of (R)-(+)-α-(l-naphthyl)ethylamine (reaction L) and (S)-(—)-α-(l-naphthyl)ethylamine (reaction M). The magnitude of optical activity and also sign of configuration of the resulting alanine change, depending on the solvent used. The discontinuity

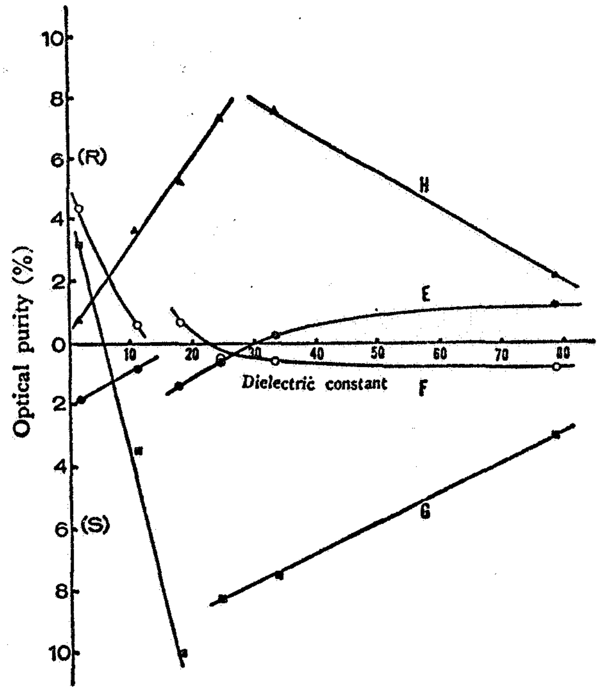


Fig. 2. Catalytic hydrogenation in the presence of *l*-ephedrine.
E Benzoylformic acid+*l*-ephedrine
F α-Acetamidoacrylic acid+*l*-ephedrine
G Oximino propionic acid+*l*-ephedrine
H Phenylpyruvic acid+*l*-ephedrine

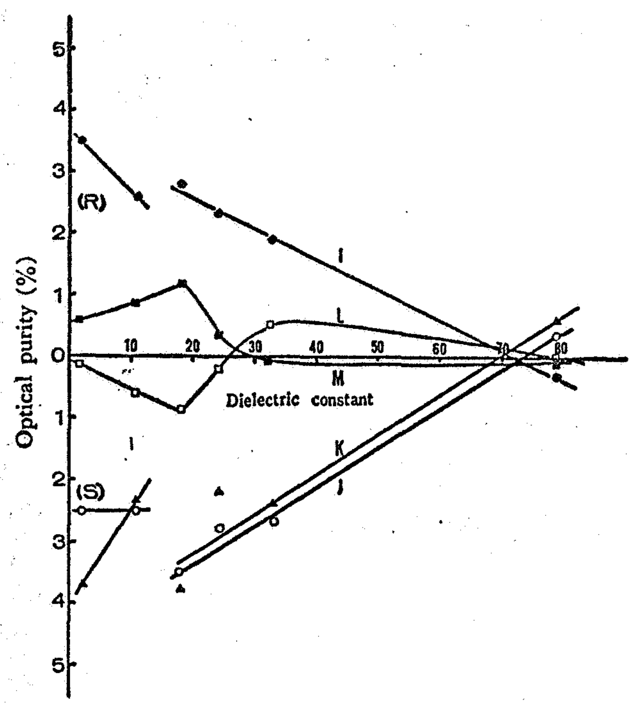


Fig. 3. Catalytic hydrogenation of α-acetamidoacrylic acid in the presence of various optically active amines.
I α-Acetamidoacrylic acid+(S)-(—)-α-methylbenzylamine
J α-Acetamidoacrylic acid+(R)-(+)-α-methylbenzylamine
K α-Acetamidoacrylic acid+(R)-(+)-α-ethylbenzylamine
L α-Acetamidoacrylic acid+(R)-(+)-α-(1-naphthyl)ethylamine
M α-Acetamidoacrylic acid+(S)-(—)-α-(1-naphthyl)ethylamine

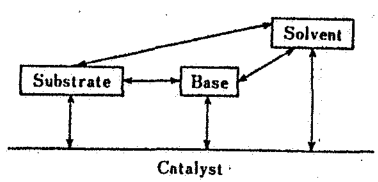
TABLE 1. CATALYTIC HYDROGENATION IN THE PRESENCE OF *l*-SPARTEINE

No.	Substrate	Amine	Solvent	Yield (%)	$[\alpha]^{25}_D$ [a]	Config.	P(%)[b]
A-1	$C_6H_5COCOOH$ (450 mg)	*l*-Sparteine (700 mg)	H_2O	400 mg (88)	−1.0 (c=2.21)	R	0.6
2			MeOH	400 (88)	−3.3 (c=1.68)	R	2.1
3			EtOH	430 (94)	−1.6 (c=2.46)	R	1.0
4			*i*-PrOH	420 (92)	−1.8 (c=2.23)	R	1.1
5			*t*-BuOH	430 (94)	−2.0 (c=2.85)	R	1.2
6			Dioxane	420 (92)	−2.1 (c=2.64)	R	1.3
B-1	$CH_2{=}C(NHAc){-}COOH$ (390 mg)	*l*-Sparteine (700 mg)	H_2O	200 mg (75)	−1.6 (c=0.34)	R	1.1
2			MeOH	250 (94)	−4.6 (c=0.34)	R	3.2
3			EtOH	240 (90)	−3.6 (c=0.15)	R	2.5
4			*i*-PrOH	230 (86)	−3.6 (c=0.28)	R	2.5
5			*t*-BuOH	240 (90)	−4.9 (c=0.20)	R	3.4
6			Dioxane	240 (90)	−4.6 (c=0.25)	R	3.2
C-1	$C_6H_5CH{=}C(NHAc){-}COOH$ (615 mg)	*l*-Sparteine (700 mg)	H_2O	420 mg (85)	−0.6 (c=2.45)	S	0.7
2			MeOH	380 (77)	−1.4 (c=1.21)	S	1.5
3			EtOH	400 (81)	+0.1 (c=2.13)	R	0.1
4			*i*-PrOH	400 (81)	+0.1 (c=2.23)	R	0.1
5			*t*-BuOH	400 (81)	−0.2 (c=2.72)	S	0.2
6			Dioxane	360 (73)	−0.6 (c=2.68)	S	0.6
D-1	$C_6H_5CH_2COCOOH$ (820 mg)	*l*-Sparteine (1.170 g)	H_2O	640 mg (78)	+0.13 (c=3.63)	R	0.6
2			MeOH	650 (79)	0 (c=3.71)		0.0
3			EtOH	600 (73)	−0.02 (c=3.62)	S	0.1
4			*i*-PrOH	620 (75)	+0.06 (c=2.88)	R	0.3
5			*t*-BuOH	630 (76)	−0.14 (c=2.84)	S	0.6

a) (S)-(+)-Mandelic acid: $[\alpha]_D = +156.2°$ (H_2O)
DNP-(S)-(+)-Alanine: $[\alpha]_D = +143.9°$ (1 N NaOH)
(R)-(+)-β-Phenyllactic acid: $[\alpha]_D = +22.2°$ (H_2O)
DNP-(S)-(−)-Phenylalanine: $[\alpha]_D = -93.7°$ (1 N NaOH).
b) Optical purity is defined as ($[\alpha]_D$ obs/$[\alpha]_D$ lit)×100.

of optical purity curves is observed in reactions I, J, and K.

An explanation of these results would be very difficult because of the complexity of the reaction system. A substrate (acid) and a base would interact with each other, and these two kinds of molecules would also be absorbed on the catalyst surface. The solvent molecule in the reaction system would also interact with the substrate, the base, and the catalyst.



In reaction (A), optical purity of mandelic acid prepared from benzoylformic acid tends to increase to the R-configuration depending on the decrease of dielectric constant of the solvent used. On the other hand, in reaction (D), optical purity of β-phenyllactic acid from phenylpyruvic acid tends to increase to the S-configuration, depending on the decrease of polarity of the solvent used. In reaction (B), the configuration of alanine from α-acetamidoacrylic acid is R and the optical purity increases to the R-configuration depending on the use of less polar solvents. However, in reaction (C), configuration of phenylalanine from α-acetamidocinnamic acid which is a similar homologue of α-acetamidoacrylic acid, is S and the direction of increase of optical purity curve is antipodal to the reaction (B). These results suggest that the phenyl residue of acetamidocinnamic acid could be an important factor to determine the conformation of the substrate on the catalyst surface.

In reaction (A) and (B), by the use of *l*-sparteine, configurations of mandelic acid and alanine are both found to be R and optical activity curves change similarly to the R-configuration, depending on the decrease of polarity of the solvent. However, in reactions (E) and (F) by the use of *l*-ephedrine, configurations of mandelic acid and alanine from the same substrate are antipodal to each other. These results suggest that the replacement of optically active base could

TABLE 2. CATALYTIC HYDROGENATION IN THE PRESENCE OF *l*-EPHEDRINE

No.	Substrate	Amine	Solvent	Yield (%)	$[\alpha]_D^{25}$ a)	Config.	P(%) b)
E-1	$C_6H_5COCOOH$ (750 mg)	*l*-Ephedrine (830 mg)	H_2O	630 mg (83)	−1.9 (*c*=2.04)	R	1.2
2			MeOH	680 (90)	−0.4 (*c*=2.15)	R	0.2
3			EtOH	650 (86)	+0.1 (*c*=2.03)	S	0.6
4			*i*-PrOH	640 (84)	+2.0 (*c*=2.06)	S	1.3
5			*t*-BuOH	630 (83)	+1.4 (*c*=1.91)	S	0.9
6			Dioxane	640 (84)	+2.8 (*c*=2.76)	S	1.8
F-1	$CH_2{=}C(NHAc){-}COOH$ (390 mg)	*l*-Ephedrine (500 mg)	H_2O	250 mg (94)	+1.2 (*c*=0.32)	S	0.8
2			MeOH	240 (90)	+0.9 (*c*=0.52)	S	0.6
3			EtOH	260 (97)	+0.7 (*c*=0.49)	S	0.5
4			*i*-PrOH	250 (94)	−1.0 (*c*=0.51)	R	0.7
5			*t*-BuOH	250 (94)	−0.8 (*c*=0.57)	R	0.6
6			Dioxane	250 (94)	−6.3 (*c*=0.26)	R	4.4
G-1	$CH_3{-}C({=}NOH){-}COOH$ (310 mg)	*l*-Ephedrine (500 mg)	H_2O	150 mg (56)	+4.4 (*c*=0.33)	S	3.0
2			MeOH	150 (56)	+10.8 (*c*=0.26)	S	7.5
3			EtOH	50 (19)	+11.8 (*c*=0.39)	S	8.2
4			*i*-PrOH	— (16) c)	+14.4 (*c*=0.41)	S	10.0
5			*t*-BuOH	— (20) c)	+5.0 (*c*=0.44)	S	3.5
6			Dioxane	— (8) c)	−4.4 (*c*=0.48)	R	3.1
H-1	$C_6H_5CH_2COCOOH$ (820 mg)	*l*-Ephedrine (825 mg)	H_2O	700 mg (85)	+0.5 (*c*=2.07)	R	2.2
2			MeOH	640 (78)	+1.7 (*c*=1.13)	R	7.6
3			EtOH	680 (82)	+1.6 (*c*=2.39)	R	7.3
4			*i*-PrOH	670 (81)	+1.2 (*c*=1.89)	R	5.2
5			*t*-BuOH	640 (78)	+0.8 (*c*=1.71)	R	3.6
6			Dioxane	550 (67)	+0.2 (*c*=2.34)	R	0.9

a) (S)-(+)-Mandelic acid: $[\alpha]_D=+156.2°$ (H_2O)
DNP-(S)-(+)-Alanine: $[\alpha]_D=+143.9°$ (1 N NaOH)
(R)-(+)-β-Phenyllactic acid: $[\alpha]_D$ +22.2° (H_2O).
b) Optical purity is defined as ($[\alpha]_D$ obs/$[\alpha]_D$ lit)×100.
c) Yields are calculated from DNP-alanine.

result in the change of the conformation of the substrate molecule on the catalyst surface. The discrepancies between reactions (A) and (B) and reactions (E) and (F) might be accounted for by the fact that *l*-sparteine has a rigid structure and *l*-ephedrine has a relatively flexible structure. The optical purity of mandelic acid (reaction E) is rather low, however, while the optical purity of β-phenyllactic acid (reaction H), which is a similar homologue of mandelic acid, is rather high (∼8%).

In reactions (J) and (K), alanine was prepared by the use of (R)-(+)-α-methylbenzylamine and (R)-(+)-α-ethylbenzylamine. The optical purity curves of (J) and (K) are almost the same as shown in Fig. 3. This implies that the difference between methyl and ethyl residue in the optically active amines does not affect the optical purity of the resulting alanine.

In order to avoid fractionation of the partially optically active amino acids during the isolation and purification procedures, a part of the amino acids were converted to DNP-derivatives. The DNP-amino acids were purified by using Celite column chromatography[10] without fractionation of the optical isomers.[11] Optical activities of mandelic acid and β-phenyllactic acid were measured before recrystallization to avoid fractionation of these optical isomers.

Experimental

All hydrogenations were carried out by the use of Parr 3910 shaker type hydrogenation apparatus at room temperature (23—25°C) with initial pressure of 40 psi.

All optical rotation measurements were carried out by the use of JASCO-ORD-UV-5 spectropolarimeter. The length of the cell used for the measurement of optical activity were 1 cm and 10 cm. All solutions for the measurement of optical activity were filtered through 0.2 μ Millipore filter or whatman No. 50 hardened filter paper. Optical rotatory

10) J. C. Perrone, *Nature*, **167**, 513 (1951); A. Court, *Biochem. J.*, **58**, 70 (1954).
11) K. Harada and K. Matsumoto, *J. Org. Chem.*, **32**, 1794 (1967); K. Harada and T. Yoshida, This Bulletin, **43**, 921 (1970).

Table 3. Catalytic hydrogenation of α-acetamidoacrylic acid in the presence of various optically active amines

No.	Substrate	Amine	Solvent	Yield (%)	$[\alpha]^{25}$ [a]	Config.	P(%)[b]
I-1	CH_2=C(NHAc)-COOH (260 mg)	(S)-$C_6H_5CH(NH_2)CH_3$ (240 mg)	H_2O	160 mg (90)	+0.4 (c=0.69)	S	0.3
2			MeOH	150 (84)	−2.8 (c=0.53)	R	1.9
3			EtOH	150 (84)	−3.3 (c=0.61)	R	2.3
4			i-PrOH	150 (84)	−4.0 (c=0.75)	R	2.8
5			t-BuOH	170 (96)	−3.7 (c=0.68)	R	2.6
6			Dioxane	160 (90)	−5.1 (c=0.67)	R	3.5
J-1	CH_2=C(NHAc)-COOH (260 mg)	(R)-$C_6H_5CH(NH_2)CH_3$ (240 mg)	H_2O	150 mg (84)	−0.5 (c=4.29)	R	0.3
2			MeOH	150 (84)	+3.8 (c=2.84)	S	2.7
3			EtOH	130 (73)	+4.1 (c=3.74)	S	2.8
4			i-PrOH	150 (84)	+5.0 (c=2.83)	S	3.5
5			t-BuOH	150 (84)	+3.6 (c=2.35)	S	2.5
6			Dioxane	160 (90)	+3.6 (c=2.97)	S	2.5
K-1	CH_2=C(NHAc)-COOH (260 mg)	(R)-$C_6H_5CH(NH_2)C_2H_5$ (340 mg)	H_2O	150 mg (84)	−0.9 (c=2.68)	R	0.6
2			MeOH	150 (84)	+3.5 (c=2.81)	S	2.4
3			EtOH	160 (90)	+3.2 (c=2.87)	S	2.2
4			i-PrOH	160 (90)	+5.4 (c=2.48)	S	3.8
5			t-BuOH	160 (90)	+3.3 (c=2.74)	S	2.3
6			Dioxane	150 (84)	+5.4 (c=2.52)	S	3.7
L-1	CH_2=C(NHAc)-COOH (260 mg)	(R)-$C_{10}H_7CH(NH_2)CH_3$ (340 mg)	H_2O	160 mg (90)	0 (c=2.56)		0
2			MeOH	160 (90)	−0.8 (c=1.85)	R	0.5
3			EtOH	160 (90)	+0.3 (c=2.33)	S	0.2
4			i-PrOH	160 (90)	+1.2 (c=2.45)	S	0.8
5			t-BuOH	160 (90)	+0.9 (c=2.49)	S	0.6
6			Dioxane	160 (90)	+0.2 (c=2.59)	S	0.1
M-1	CH_2=C(NHAc)-COOH (260 mg)	(S)-$C_{10}H_7CH(NH_2)CH_3$ (318 mg)	H_2O	150 mg (84)	+0.3 (c=3.81)	S	0.2
2			MeOH	160 (90)	+0.1 (c=4.06)	S	0.1
3			EtOH	160 (90)	−1.0 (c=2.74)	R	0.7
4			i-PrOH	150 (84)	−1.9 (c=3.05)	R	1.3
5			t-BuOH	150 (84)	−1.1 (c=4.02)	R	0.8
6			Dioxane	160 (90)	−0.8 (c=5.23)	R	0.6

a) DNP-S(+)-Alanine: $[\alpha]_D$=+143.9° (1 N NaOH).
b) Optical purity is defined as ($[\alpha]_D$ obs/$[\alpha]_D$ lit)×100.

dispersion curves of some of the samples were recorded in order to determine that the rotatory power of the samples was due to the optically active specific compounds which formed by the asymmetric hydrogenation.

Elemental analyses were carried out by Micro-Tech Laboratories, Inc., Skokie, Illinois. Melting points were measured by the use of Mel-Temp apparatus. Melting points measured were uncorrected.

Dielectric constants of the solvents used were as follows:

H_2O	78.5
MeOH	32.6
EtOH	24.3
i-PrOH	18.3
t-BuOH	10.9
Dioxane	2.2

Optically active amines used were: l-(−)-sparteine, $[\alpha]_D^{25}$ −4.59° (benzene); l-(−)-ephedrine, $[\alpha]_D^{25}$ −5.13° (ethanol); S-(−)-α-methylbenzylamine, $[\alpha]_D^{25}$ −42.4° (benzene); R-(+)-α-methylbenzylamine, $[\alpha]_D^{25}$ +40.0° (benzene); R-(+)-α-ethylbenzylamine, $[\alpha]_D^{25}$ +21.7° (benzene); R-(+)-α-(1-naphthyl)ethylamine, $[\alpha]_D^{25}$ +77.8° (benzene); S-(−)-α-(1-naphthyl)ethylamine, $[\alpha]_D^{25}$ −80.0° (benzene).

Hydrogenation of Benzoylformic Acid with l-*Sparteine.* A mixture of benzoylformic acid (450 mg, 0.003 mol) and *l*-sparteine (700 mg, 0.003 mol) in 15 m*l* of water was subjected to hydrogenation at room temperature with 500 mg of 5% palladium on charcoal. After the hydrogenation was over, the catalyst was removed by filtration and the filtrate was concentrated under reduced pressure. The residual oil was dissolved in 6 N hydrochloric acid and the mixture was extracted with ether several times. The combined ethereal extract was washed once with water and dried with anhydrous sodium sulfate. After evaporation of ether, mandelic acid was crystallized. Yield, 400 mg (88%), mp 116.5—117°C, $[\alpha]_D^{25}$ −0.96° (*c* 2.21, H_2O), optical purity 0.6%. A part of this sample was recrystallized from benzene, mp 120—121°C.

Found: C, 62.92; H, 5.25%. Calcd for $C_8H_8O_3$: C, 63.15; H, 5.30%.

Similar experiments by using other solvents are listed in Table 1 (A).

Hydrogenation of Benzoylformic Acid with l-*Ephedrine.* The hydrogenation procedures are the same as described above. The results are summarized in Table 2 (E).

Hydrogenation of α-Acetamidoacrylic Acid with l-*Sparteine.* A mixture of α-acetamidoacrylic acid (390 mg, 0.003 mol) and *l*-sparteine (700 mg, 0.003 mol) in 30 m*l* of water was hydrogenated with 5% palladium on charcoal (500 mg). After hydrogenation was over, the catalyst was removed by filtration. The filtrate was concentrated *in vacuo.* The residual oil was hydrolyzed with 6 N hydrochloric acid (20 m*l*) under reflux for 5 hr. The hydrolyzate was evaporated to dryness under reduced pressure. The residue was dissolved in 10% aqueous sodium carbonate solution and the solution was extracted with ether repeatedly to remove sparteine. The aqueous solution was acidified and was evaporated to dryness *in vacuo.* The residual amino acid hydrochloride was extracted with absolute ethanol. The ethanol solution was evaporated under reduced pressure. Free alanine was obtained by using a Dowex-50 ion exchange column. Yield, 200 mg (75%), DNP-alanine, $[\alpha]^{25}$ −1.56° (*c* 0.34, 1 N NaOH), optical purity, 1.1%, mp 178—179°C.

Found: C, 42.50; H, 3.53; N, 16.9%. Calcd for $C_9H_9O_6N_3$: C, 42.36; H, 3.55; N, 16.47%.

Similar experiments by the use of other solvents are summarized in Table 1 (B).

Hydrogenation of α-Acetamidoacrylic Acid with l-*Ephedrine.* The hydrogenation procedures are similar to those described above. The results are summarized in Table 2 (F).

Hydrogenation of α-Acetamidoacrylic Acid with S-(−)-α-Methylbenzylamine. The procedures are similar to those described above. The results are summarized in Table 3 (I, J, K, L, M).

Hydrogenation of α-Acetamidocinnamic Acid with l-*Sparteine.* The procedures are similar to those described above. From α-acetamidocinnamic acid (615 mg, 0.003 mole) and *l*-sparteine (700 mg, 0.003 mole), 420 mg of phenylalanine was obtained (85%), DNP-phenylalanine, $[\alpha]^{25}$ −0.61° (*c* 2.45, 1 N NaOH), optical purity 0.65%, mp 216.5—217.5°C.

Found: C, 54.11; H, 3.84; N, 12.57%. Calcd for $C_{15}H_{13}O_6N_3$: C, 54.38; H, 3.96; N, 12.68%.

Other results obtained by the use of other solvents are listed in Table 1 (C).

Hydrogenation of Phenylpyruvic Acid with l-*Epherine.* Phenylpyruvic acid (820 mg, 0.005 mole) and *l*-ephedrine (825 mg, 0.005 mole) were dissolved in 30 m*l* of water. The mixture was hydrogenated and β-phenyllactic acid was isolated as above. Yield, 700 mg (85%), mp 94—95°C, $[\alpha]_D^{25}$ +0.48° (*c* 2.07, H_2O), optical purity 2.2%. A part of the sample was recrystallized from benzene, mp 96—97°C.

Found: C, 62.92; H, 5.25%. Calcd for $C_9H_{10}O_3$: C, 63.15; H, 5.30%.

Other results obtained by using other solvents are summarized in Table 2 (H).

This work was supported by Grant No. NSG 10-007-052 of the National Aeronautics and Space Administration.